The Egyptian Journal of Radiology and Nuclear Medicine (2013) **44**, 417–423

Egyptian Society of Radiology and Nuclear Medicine

The Egyptian Journal of Radiology and Nuclear Medicine

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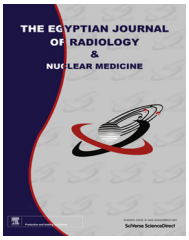

ORIGINAL ARTICLE

Preoperative assessment of vascular invasion in exocrine pancreatic cancer by multidetector CT

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Received 21 June 2012; accepted 13 March 2013
Available online 3 May 2013

KEYWORDS

Pancreatic cancer;
Vascular invasion;
MDCT

Abstract *Purpose:* To evaluate multidetector CT (MDCT) signs of vascular invasion in pancreatic carcinoma.
Patients and methods: Retrospective review of preoperative dynamic MDCT of 42 patients with pathologically proven pancreatic carcinoma.
Results: Surgically confirmed invaded vessels were 19 arteries and 33 veins. Multiple signs of vascular invasion were assessed.
Conclusion: Significant advances have been made in the ability of MDCT to visualize pancreatic cancer and to stage disease when close attention is paid to technique with special attention to multiple signs of vascular invasion.

1. Introduction

Primary prevention is the most effective approach to reduce the incidence of pancreatic cancer because it is the fourth leading cause of cancer related death in the world with an overall 5-year survival rate of less than 4% (1). Currently, surgery remains the only option for cure (2).

The poor prognosis is usually due to late diagnosis (3). Exocrine tumors are the most common types of pancreatic cancer with the adenocarcinoma representing about 90% of cases (4).

Surgical resection is the optimal curative treatment; however, only 20% of patients have resectable disease at diagnosis (1,2,5,6).

Despite the advances of imaging, CT scan remains the main imaging modality, although about 25–30% of patients who are thought to have resectable lesions at CT have unresectable lesions at surgery. There is no evidence of the optimal preoperative imaging modality for evaluation of patients with suspected pancreatic cancer; however, assessment of vascular invasion is an important issue for determining resectability as resectability depends on the type of the vessel involved

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Peer review under responsibility of Egyptian Society of Radiology and Nuclear Medicine.

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Table 1 MDCT signs of involved arteries.

MDCT signs	SMA	CA	HA	Total
> 50% Circumferential involvement	7	4	1	12
Vascular infiltration (wall irregularity)	2	1	1	4
Diameter stenosis	2	1	–	3
Vascular occlusion	–	–	–	–

SMA, superior mesenteric artery; CA, celiac artery; HA, hepatic artery.

Table 2 MDCT signs of involved veins.

MDCT signs	SMV	PV	Total
> 50% circumferential involvement	8	2	10
Vascular infiltration (wall irregularity)	8	4	12
Diameter stenosis	7	2	9
Vascular occlusion	2	–	2

SMV, superior mesenteric vein; PV, portal vein.

Table 3 Number and percentages of MDCT signs in involved arteries.

MDCT signs	SMA	CA	HA	Total	%
Vascular contact	7/11	4/6	1/2	12/19	63.1
Vascular infiltration (wall irregularity)	2/11	1/6	1/2	4/19	21.1
Diameter stenosis	2/11	1/6	0/2	3/19	15.8
Vascular occlusion	0/11	0/6	0/2	0/19	0

SMA, superior mesenteric artery; CA, celiac artery; HA, hepatic artery.

Table 4 Number and percentages of MDCT signs in involved veins.

MDCT signs	SMV	PV	Total	%
> 50% Vascular contact	8/21	2/4	10/33	30.3
Vascular infiltration (wall irregularity)	10/21	2/4	12/33	36.4
Diameter stenosis	7/21	2/4	9/33	27.3
Vascular occlusion	2/21	0/4	2/33	6

SMV, superior mesenteric vein; PV, portal vein.

and the degree of vascular involvement. Recently, multidetector CT (MDCT) allowed improvement in assessment of preoperative vascular invasion (7–9).

To our knowledge, previous studies stated variable negative predictive values of MDCT in evaluating pancreatic carcinoma with about 20–55% of patients incorrectly diagnosed as having resectable tumor on CT and found to have unresectable tumor at surgery. Most often, this type of misdiagnosis is due to undetected vascular invasion (7,8).

The aim of this study was to evaluate MDCT signs of preoperative vascular invasion in pancreatic carcinoma.

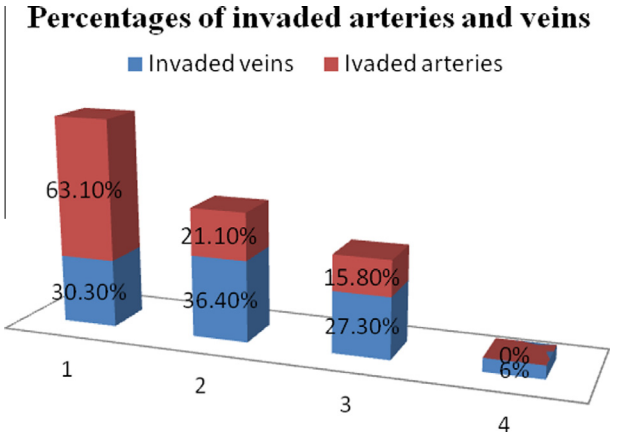

Fig. 1 Number and percentages of MDCT signs in invaded arteries and veins, (1) circumferential involvement (any degree for arteries, > 50% for veins), (2) vascular infiltration (wall irregularity), (3) caliber stenosis and (4) vascular occlusion.

2. Patients and methods

2.1. Study population

A retrospective review of preoperative dynamic MDCT studies of 42 patients (16 females and 26 males with ages ranging from 43 to 76 years, mean age 60.2 years) with pathologically proven pancreatic carcinoma who underwent operations (surgical resection, exploration or surgical bypass) was done at National Cancer Institute, Cairo University. Patients underwent surgical operations within 1–3 weeks after MDCT. No informed consent was taken since it was a retrospective study, approved by institutional ethics committee.

2.2. Imaging methods and MDCT imaging protocol

CT studies were performed by using a 64 MDCT scanner (Light speed 64 slice VCT, GE Healthcare, Milwaukee, WI, USA) before and after IV contrast medium administration. The pre contrast series was taken by using a 5 mm slice thickness.

The post contrast study was done using about 120–180 ml of low osmolar non ionic contrast medium (iohexol, Omnipaque 300; Amersham Health, Oslo, Norway) at a flow rate of 5 ml/s. The volume of contrast material was calculated according to the body weight of the patient (2 ml of contrast material per kilogram of body weight).

Patients received about 500 ml of water about 1 h prior to scan and about 250 ml of additional water immediately before scanning for better assessment of peripancreatic vascular structures, followed by IV injection of nonionic contrast medium using a power injector.

MDCT scan was performed with the following acquisition parameters: 200 mAs, 120 kVp, 512 × 512 matrix, 1.1 pitch, 64 × 0.625 mm collimation, 1 mm slice thickness, 0.6 mm reconstruction increment.

Automated bolus tracking with bolus detection at the level of the descending aorta above the diaphragm ensured accurate timing of the data acquisition in the arterial phase.

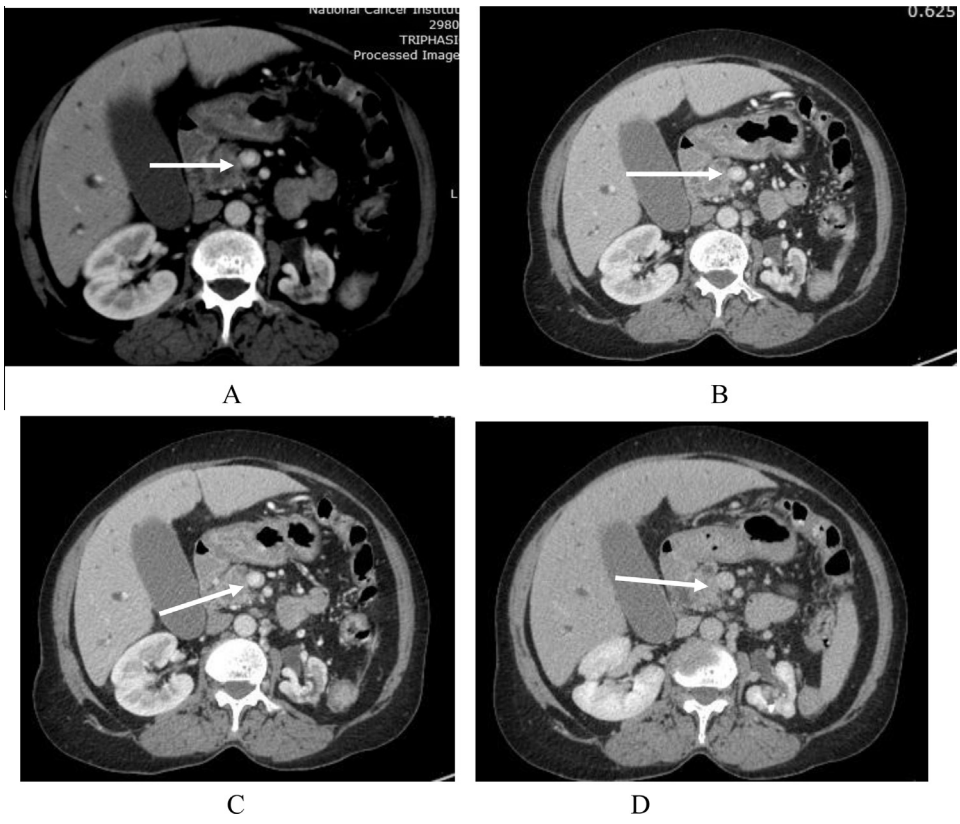

Fig. 2 Pathologically proved pancreatic head carcinoma in 51 year old female, (A), (B), (C) portal phase and (D) pancreatic parenchymal phase. The lesion showed < 50% circumferential involvement of superior mesenteric vein (arrow), the case was resectable.

Triphasic scan including arterial phase, pancreatic parenchymal and hepatic portal phase was used.

Optimal scanning delay after triggering of bolus tracking at 50 H of aortic contrast enhancement was 5–10 s for the peripancreatic arterial phase, 15–20 s for the pancreatic parenchymal phase, and 45–55 s for the portal phase.

Multiplanar reformatted images were obtained at a post-processing workstation.

2.3. Image analysis and interpretation

All CT images were analyzed and revised by three radiologists with evaluation of 3 arteries (celiac, hepatic and superior mesenteric) and 2 veins (portal and superior mesenteric veins).

The degree of vascular involvement was estimated by circumferential vessel involvement by tumor. Circumferential involvement was categorized as stage 1, less than one quarter circumference of vessel contiguous with tumor; stage 2, between one quarter and one half of vessel circumference contiguous with tumor; stage 3, more than one half and up to three quarters of vessel circumference contiguous with tumor; and stage 4, more than three quarters of vessel circumference contiguous with tumor. Stages 1 and 2 were considered resectable, whereas grades 3 and 4 were considered unresectable. Borderline resectable was used for cases of hard distinction between resectable and unresectable.

Our patients were classified into resectable and borderline resectable and unresectable.

The criteria for unresectability and the degree of vascular involvement, more than 50% circumferential vascular involvement were used as a sign of invasion.

Criteria of unresectability included large tumors (more than 2 cm in size), presence of local or distant metastasis and vascular invasion of celiac trunk, hepatic artery, superior mesenteric artery, portal vein or superior mesenteric vein.

We focused on vascular invasion in our study with the use of degree of vascular involvement, more than 50% circumferential vascular involvement as a sign of invasion.

With recent advances in pancreatic imaging, the distinction between resectable (stages I and II), locally advanced (stage III) and unresectable (stage IV) disease may be quite hard and the term ''borderline resectable'' is emerging to define these tumors (10).

Borderline resectable tumors are defined as those with tumor abutment of < 180° (< 50%) of the SMA or celiac axis, short segment abutment or encasement of the common hepatic artery typically at the gastroduodenal artery origin, SMV-PV abutment with impingement and narrowing or segmental venous occlusion with sufficient venous flow above and below the occlusion to allow an option for venous reconstruction (2,11).

Teardrop sign of superior mesenteric vein was considered as a sign of unresectability (12).

Regarding isolated venous involvement, most surgeons do not consider it as a contraindication for surgery as they perform partial venous resection with end-to-end anastomosis or using bypass grafts (1).

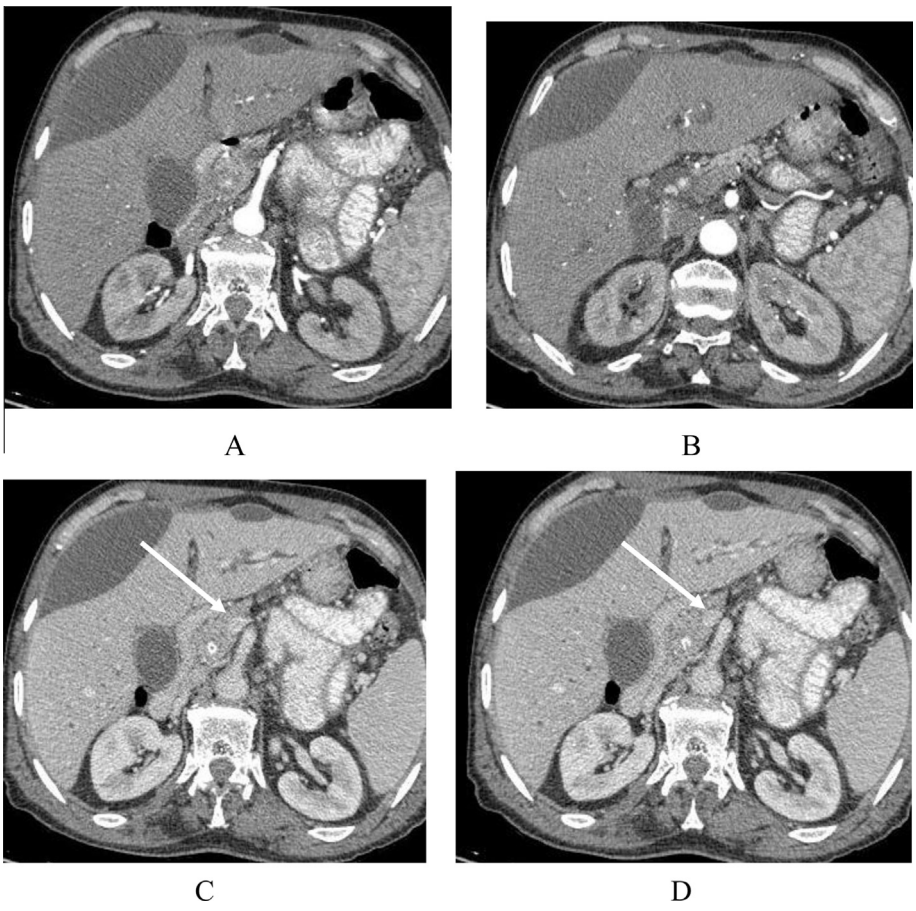

Fig. 3 Pathologically proved pancreatic head carcinoma in 72 year old male, (A), (B), arterial phase, (C), (D) venous phase. The lesion showed > 50% circumferential involvement of superior mesenteric vein seen in venous phase images (arrow), the case was resectable. Two non enhanced subcapsular bilomas were noted.

The evaluated signs of involved vessels were:

- Vascular contact.
- Vessel wall irregularity (vascular infiltration).
- Diameter stenosis.
- Vascular occlusion.

2.4. Comparison with operative data and histologic examination

Results were confirmed, compared and correlated with the operative and pathologic results. Surgically confirmed invaded vessels were analyzed in detail.

2.5. Statistical analysis

Statistical calculations were performed using statistical software (statistics program SPSS/PC).

Statistical tests were performed on signs of vascular invasion to check for any significant difference between the invaded arteries and veins. *P* value of 0.05 was used to show statistical significance.

3. Results

12 of 42 cases were surgically resectable and 30 cases were surgically unresectable.

210 vessels were examined in all 42 cases (5 vessels in each case). In the 30 unresectable cases, 52 vessels were invaded (in many cases there were more than 1 vessel involved).

The involved vessels confirmed at surgery were 52 (19 arteries and 33 veins).

Occlusion was seen in 6% of involved veins and was not seen in involved arteries. Circumferential vascular involvement was seen in 63.1% of involved arteries compared to 30.3% of involved veins. Vascular infiltration was seen in 21.1% of involved arteries and in 36.4% of involved veins. Diameter stenosis was seen in 15.8% of involved arteries compared to 27.3% of involved veins.

MDCT signs of involved arteries and veins respectively are described in Tables 1 and 2, while statistical data for number and percentages of MDCT signs in involved arteries and veins respectively are shown in Tables 3 and 4. The number and percentages of different MDCT signs in invaded arteries and veins are shown in Fig. 1, while Figs. 2–7 showed varieties of cases in our study.

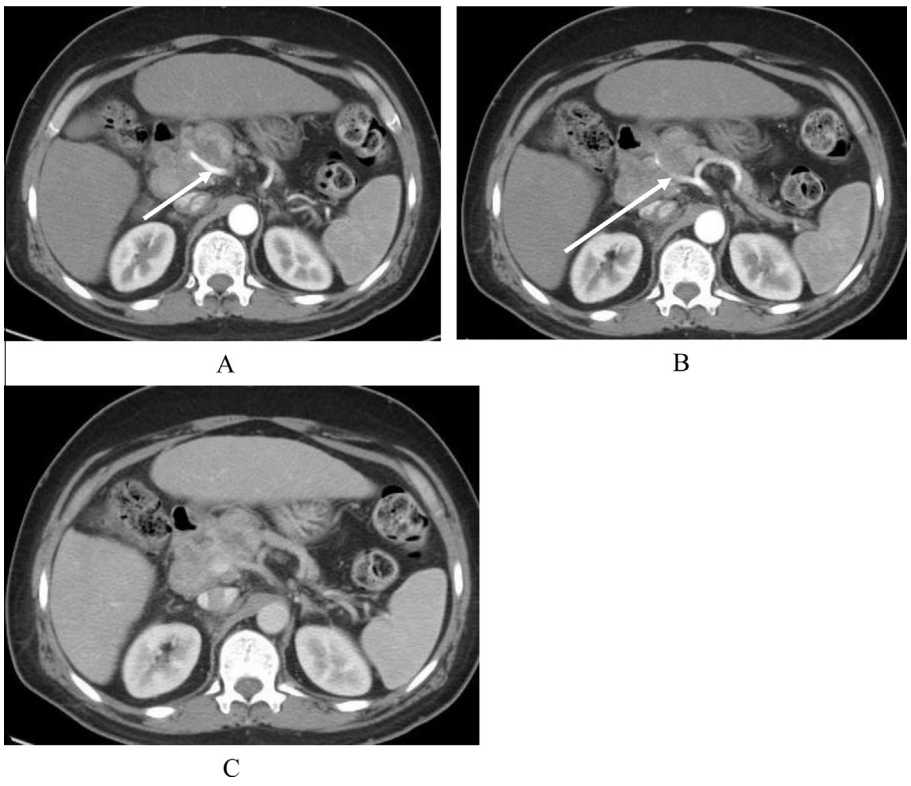

Fig. 4 Pathologically proved pancreatic head carcinoma in 60 year old male, (A), (B) arterial phase and (C) hepatic portal phase. The lesion was encasing the hepatic artery which showed wall irregularity denoting vascular infiltration (arrow), the case was unresectable.

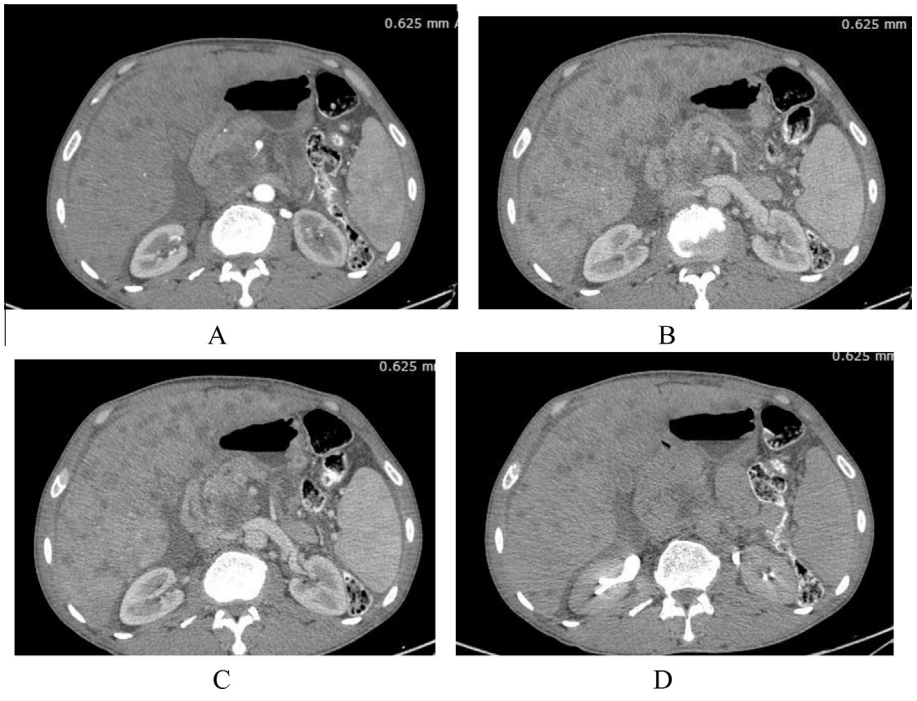

Fig. 5 Pathologically proved pancreatic head carcinoma in 62 year old female with signs of unresectability on dynamic MDCT study, (A) arterial phase, (B), (C) pancreatic parenchymal phase and (D) portal venous phase. The lesion showed $>50\%$ circumferential involvement of superior mesenteric artery and vein with thrombosed SMV and liver metastases, definite signs of unresectability.

Fig. 6 Pathologically proved pancreatic head carcinoma located in uncinate process in 60 year old male. The lesion was located away from the vascular structures and diagnosed as resectable.

12 of 42 cases (28.6%) were surgically resectable and 30 cases (71.4%) were surgically unresectable. All the 12 patients diagnosed as resectable underwent surgical operations.

The overall accuracy of signs of vascular invasion was 75%.

Nine out of the 12 (75%) had successful tumor resection with positive predictive value for resectability and accuracy of 75%, while 3 (25%) patients had unresectable pancreatic tumors (two patients showed invasion of superior mesenteric vein and the third one showed involvement of superior mesenteric artery). The three patients underwent palliative procedures.

The patients that were believed to have resectable lesions on the basis of MDCT were 3 out of 12 (25%) with the overall accuracy of 75%. 9 patients (21.4% of all 42 patients) had successful tumor resection.

4. Discussion

Pancreatic cancer is associated with a poor prognosis, and surgical resection remains the only chance for curative therapy (9).

In addition to assessing tumor contiguity with vessels, it was found that changes in vessel diameter and vascular occlusion are helpful signs for evaluation of vascular involvement. MDCT is regarded as the most important non-invasive staging technique in detecting vascular invasion (1).

It was found that the signs of arterial and venous involvement are multiple, so it is necessary to evaluate MDCT signs separately for arterial and venous involvement (1,3).

The major reason for the different CT signs of arterial and venous invasion is that the venous wall is thinner and more flexible than the arterial wall, so when the vein is involved it tends to be irregular and narrowed. For the same reason, venous occlusion is more common than arterial occlusion (13).

Regarding isolated venous involvement, most pancreatic surgeons do not consider it as a contraindication for surgery as they perform partial venous resection with end-to-end anastomosis or using bypass grafts. Venous resections and recon-

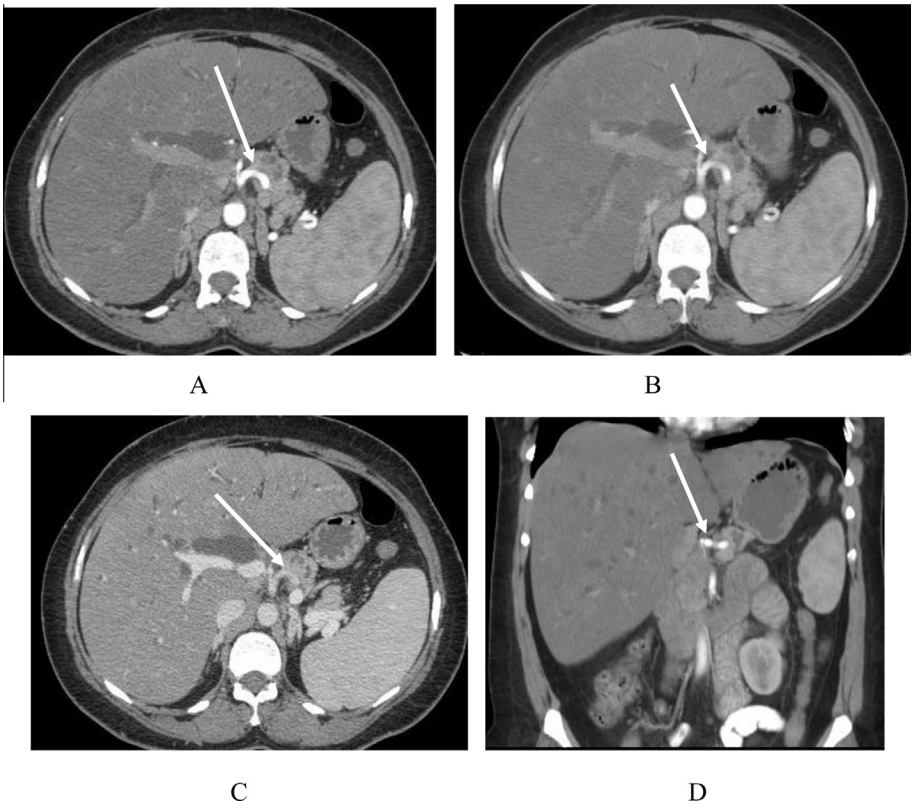

Fig. 7 Pathologically proved pancreatic body and tail carcinoma: 63 year old female with signs of vascular invasion on dynamic MDCT study, (A), (B) arterial phase, (C) hepatic portal phase and (D) reformatted coronal image for the arterial phase. The lesion was away from celiac trunk and mesenteric vessels but was in contact with splenic artery which showed focal caliber stenosis (arrow). The case was resectable as involvement of splenic vessels does not preclude resection.

structions are increasingly performed as the technique is feasible and reliable, with morbidity and mortality similar to pancreaticoduodenectomy without vascular reconstruction (14).

Borderline resectable tumors are defined as those with tumor abutment of $<180°$ ($<50\%$) of the SMA or celiac axis, short segment abutment or encasement of the common hepatic artery typically at the gastroduodenal artery origin, SMV-PV abutment with impingement and narrowing or segmental venous occlusion with sufficient venous flow above and below the occlusion to allow an option for venous reconstruction. Most of the patients who meet these CT criteria are candidates for preoperative systemic chemotherapy followed by chemoradiation since they are at a high risk for margin positive resection with upfront surgery (2).

In our study vascular occlusion was seen in 6% of involved veins and was not seen in involved arteries. Circumferential vascular contact was seen more in involved arteries (63.1%) than in involved veins (30.3%). Vascular infiltration was seen more in involved veins (36.4%) than in involved arteries (21.1%). Diameter stenosis was seen in 15.8% of involved arteries compared to 27.3% of involved veins.

The observations in this study have been supported by previous reports and published studies (1,9,12,13).

5. Conclusion

Significant advances have been made in the ability of MDCT to visualize pancreatic cancer and to stage disease when close attention is paid to technique with special attention to multiple signs of vascular invasion.

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